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LIQUID TREATMENT APPARATUS FOR  
PROVIDING A FLOW OF PRESSURIZED LIQUID

TECHNICAL FIELD

This invention relates to apparatus for providing a  
10 flow of pressurized liquid. The apparatus has particular  
application to the filtering of pressurized liquid to separate  
the pressurized liquid into a permeate portion and a concentrate  
portion and may be utilized for the desalinization of sea water.

15 BACKGROUND ART

My pending U.S. Patent Application Serial No.  
08/228,884, filed April 18, 1994, discloses a system which can be  
utilized to desalinate sea water. There are, of course, many  
prior art systems which utilize reverse osmosis to accomplish  
20 such objective. Typically, prior art desalinization systems are  
very expensive to operate and difficult to service. The system  
of my above-referenced pending U.S. Patent Application Serial No.  
08/228,884, filed April 18, 1994, addresses this problem. The  
apparatus disclosed and claimed herein represents another  
25 approach to solving the problems inherent in the prior art.

The apparatus of the present invention utilizes a piston of a particular character in the apparatus. While reversible pistons per se are known in the prior art as part of hydraulic circuits, the character of the piston and related mechanism employed in the present system differs in regard to both structure and manner of operation. U.S. Patent No. 4,793,153, issued December 27, 1988 discloses a typical prior art hydraulic circuit employing a reversible piston to accomplish "energy recovery" in a mixed-phase motor in a refrigeration system.

#### DISCLOSURE OF INVENTION

The apparatus of the present invention provides a highly efficient, relatively low-cost approach for desalinization of sea water or for other operations wherein it is desired to flow a liquid under intensified pressure conditions. The apparatus employs a minimal number of seals and can be powered by liquid under low pressure, such as that produced by a conventional low pressure pump.

The present apparatus employs a minimal number of operating parts which cooperate to substantially increase the pressure of the liquid as compared to the pressure thereof when introduced into the apparatus or system. High pressures can readily be developed with the present invention, thus making it ideal for cross-flow filtration applications, including reverse osmosis filtration systems, wherein high pressures are necessary.

The apparatus can also be utilized as a fluid powered high pressure pump for other applications.

The liquid treatment apparatus of the present invention is for providing a flow of pressurized liquid and includes a 5 hydraulic cylinder defining a cylinder interior.

A divider divides the cylinder interior into first and second compartments.

A first piston head is within the cylinder interior, the first piston head being movably mounted in the first 10 compartment and forming a liquid-tight seal with the hydraulic cylinder to subdivide the first compartment to a first set of two subcompartments, said subcompartments of the first set of two subcompartments located at opposed sides of the first piston head.

15 A second piston head is within the cylinder interior spaced from the first piston head, the second piston head being movably mounted in the second compartment and forming a liquid-tight seal with the hydraulic cylinder to divide the second compartment into a second set of two subcompartments, said 20 subcompartments of the second set of two subcompartments located at opposed sides of the second piston head.

A double-ended ram member is movably mounted within the cylinder interior and located between the first piston head and the second piston head. A first end of the ram member is 25 unattached to but engageable with the first piston head within a single subcompartment of the first set of two subcompartments and

a second end of the ram member is unattached to but engageable with the second piston head within a single subcompartment of the second set of subcompartments. The ram member extends through the divider, is movable relative to the divider, and forms a 5 fluid-tight seal with the divider.

The apparatus also includes first liquid flow path defining means defining a first liquid flow path extending between the two subcompartments of the first set of two subcompartments.

10 Second liquid flow path defining means defines a second liquid flow path extending between the two subcompartments of the second set of two subcompartments.

15 Pressurized liquid delivery means is provided having an outlet for pressurized liquid. Control means alternately introduces pressurized liquid from the pressurized liquid delivery means outlet into the first and second compartments to cause reciprocal movement of the piston heads and ram member within the cylinder interior and pressurization and flow of liquid through the liquid flow paths from the subcompartments of 20 the sets of two subcompartments not accommodating a ram member end to their respective subcompartments accommodating a ram member end.

25 Liquid exit flow path defining means defines a liquid exit path communicating with the liquid flow paths for discharging excess pressurized liquid from the subcompartments

not accommodating a ram member and not entering the subcompartments accommodating a ram member end.

In a preferred embodiment, the apparatus includes filter means operatively associated with the first and second liquid flow path defining means for receiving pressurized liquid from the first and second liquid flow paths and filtering the pressurized liquid.

Other features, advantages, and objects of the present invention will become apparent with reference to the following description and accompanying drawings.

#### BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a schematic view illustrating an embodiment of apparatus constructed in accordance with the teachings of the present invention incorporating a filter, the embodiment shown during one stage of operation thereof;

Fig. 2 is a view similar to Fig. 1 but illustrating the apparatus embodiment during another stage of operation; and

Fig. 3 is a view similar to Fig. 1 but of an embodiment of the apparatus not employing a filter.

#### MODES FOR CARRYING OUT THE INVENTION

Referring now to Figs. 1 and 2, apparatus constructed in accordance with the teachings of the present invention includes a hydraulic cylinder 10 defining a cylinder interior 12. A divider 14 is disposed within the cylinder interior and divides

the cylinder interior into first compartment 16 and second compartment 18.

A first floating piston head 20 is movably mounted in the first compartment 16 and subdivides the first compartment 5 into a first set of two subcompartments 22, 24 located at opposed sides of the first piston head 20. A seal 26 is disposed about first piston head 20 to maintain a fluid-tight seal with the hydraulic cylinder.

A second piston head 30 having a seal 32 thereabout is 10 movably mounted in second compartment 18 forming a liquid-tight seal with the hydraulic cylinder and dividing the second compartment into a second set of two subcompartments 36, 38. Subcompartments 36, 38 are located at opposed sides of the second 15 piston head 30. Piston heads 20, 30 are in the nature of floating piston heads, slidable back and forth within their respective compartments upon application of outside forces thereto.

A double-ended ram member 40 is movably mounted within the cylinder interior and located between piston heads 20, 30. 20 One end 42 of the ram member is unattached to but engageable with the first piston head within subcompartment 22. The other end 44 of the ram member is unattached to but engageable with second piston head 30 within subcompartment 36. This arrangement compensates for any misalignment and extends the life of seals 25 associated with the piston heads.

The ram member 40 extends through divider 14, is reciprocally movable relative to the divider, and forms a fluid-tight seal with the divider. An O-ring 46 is illustrated for such latter purpose.

5 A conduit or flow line 50 defines a liquid flow path extending between subcompartments 22 and 24. A conduit or flow line 52 extends between subcompartments 56 and 58.

10 A pump 54 has an outlet 56 communicating with flow lines 58, 60, the pump pumping liquid from a source or supply thereof 62. The liquid may, for example, be sea water. Flow lines 58, 60 communicate respectively with flow lines 50, 52 through check valves 64 and 66. Check valves 68, 70 are disposed in flow lines 50, 52, respectively, as illustrated.

15 Flow lines 50 and 52 converge at a common flow line 72 leading to the input of a reverse osmosis filter 74 which may be of any suitable well known construction. As is conventional, reverse osmosis filter 74 will serve to separate out a permeate portion in the form of fresh water if the sea water introduced thereinto is pressurized to a certain extent. Arrow 76 in the 20 drawings indicates the flow of a permeate or product portion out of the filter.

25 The remaining portion, the concentrate or brine portion, flows through a conduit 78 and thence through a retrack valve 80. A segment of flow line 50 between retrack valve 80 and cylinder 10 delivers the concentrate or brine portion to the subcompartment 24 as indicated by the arrows.

The positioning of retrack valve 80 is determined by the positioning of an associated pilot valve 82. In Fig. 1, both the retrack valve 80 and pilot valve 82 are in their respective right-most positions wherein pressurized liquid from pump 54 will 5 pass from line or conduit 58 through pilot valve 82 and thence through a conduit 84 to the left end of retrack valve 80.

Also with reference to Fig. 1, the pressurized liquid from pump 54 will displace check valve 66 and pass into subcompartment 38 as indicated by the arrows. This will cause a 10 build-up of liquid pressure in the subcompartment 38 urging second piston head 30 to the left as shown in Fig. 1. The second piston head will engage end 44 of ram member 40 causing the ram member to move left and engage first piston head 20 at end 42 of the ram member.

15 Piston head 20 will cause displacement of liquid in first compartment 16 into flow line or conduit 50 and displacement of check valve 68.

The liquid displaced from first compartment 16 will then enter filter 74 with a portion thereof passing as 20 previously described through conduit 78 and retrack valve 80 into subcompartment 24. It will be appreciated, however, that not all of the liquid displaced from subcompartment 22 will enter subcompartment 24, because a portion of the ram member occupies the subcompartment 24. That is, the volume of 25 subcompartment 22 will decrease at a faster rate than the volume of subcompartment 24 increases. This will result in substantial

pressurization of the liquid exiting subcompartment 22, with the difference in the amount of liquid being forced to pass out of the reverse osmosis filter 74 as permeate due to closure of check valve 70 in line 52.

5 During this stage of the operation, the pressure of the liquid in subcompartment 36 will be essentially zero since the liquid contents thereof (brine in the case of salt water) will pass through a discharge line 84 through retrack valve 80.

10 In summary, the liquid in subcompartment 38 will be at the outlet or pressure of pump 54, e.g. 80 psi. The pressure in subcompartment 36 will be essentially zero, and the pressure of liquid in subcompartments 22, 24 will be considerably higher, e.g. 800 psi. The amount of increase will generally correspond to the ratio of the cross-sectional area of the ram to the cross-  
15 sectional area of the cylinder.

Fig. 2 illustrates the situation which exists sometime after second piston head 30 has contacted pilot valve 82 and displaced same to the left along with consequent displacement to the left of retrack valve 80. Now the pump 54 directs 20 pressurized liquid to subcompartment 22 with piston heads 20 and 30 and ram member 40 moving to the right to pressurize liquid in subcompartments 36, 38 with consequent discharge of highly pressurized liquid from subcompartment 38 through filter 74, retrack valve 80 and into subcompartment 36, the excess highly 25 pressurized liquid exiting the filter 74 as a permeate portion in the form of fresh water. Of course, this entire cycle will keep

repeating itself as long as pump 54 delivers drive pressure fluid to the rest of the system.

Fig. 3 illustrates an alternative embodiment wherein the apparatus does not incorporate a filter. Excess high pressure liquid (the amount that cannot be accommodated by a subcompartment housing a ram member end), rather than being directed through a filter, is delivered to an outlet 90. Thus, this form of the apparatus can be considered in the nature of a high pressure pump which receives liquid under relatively low pressure, intensifies the liquid pressure, and delivers a portion of the pressure intensified liquid to a given location.

The arrangement of Fig. 3 also differs from that of Figs. 1 and 2 in that it is essentially a "closed" system with drain or discharge passing through retrack valve 80 flowing through line 92 back to liquid supply source 62. Likewise, the pilot drain liquid can also be returned to the source as shown.